Helium Cryogenic Systems for the LEP2 and LHC Projects at CERN

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ABSTRACT

CERN is presently operating a large distributed 4.5 K helium cryo
kW@4.5 K equivalent) for cooling the superconducting acceleration c
km circumference LEP2 lepton collider. This also constitutes the f
cryogenic system (about 150 kW@4.5 K equivalent) for the future
Collider (LHC), the high-field superconducting magnets of which
superfluid helium. We briefly describe the main features of each sy
progress of their development, construction and operation.

INTRODUCTION

Particle physics has volens nolens become a prime user of large
cryogenics, through the generalized use of superconducting device
guiding and focusing high-energy particles in recent accelerators ar
specific requirements, both qualitative and quantitative, set by a
represented a strong driving force to stimulate technological develo
push helium cryogenics out of the laboratory into industrial-scal
operating with high reliability and high efficiency. At CERN, the I
for Particle Physics, this evolution took place in the last d
superconducting quadrupoles of the LEP high-luminosity insertions
upgrade (LEP2) using superconducting acceleration cavities in larg
Large Hadron Collider (LHC) project based on high-field superconduc
superfluid helium cryogenics on an unprecedented scale (Figure 1).

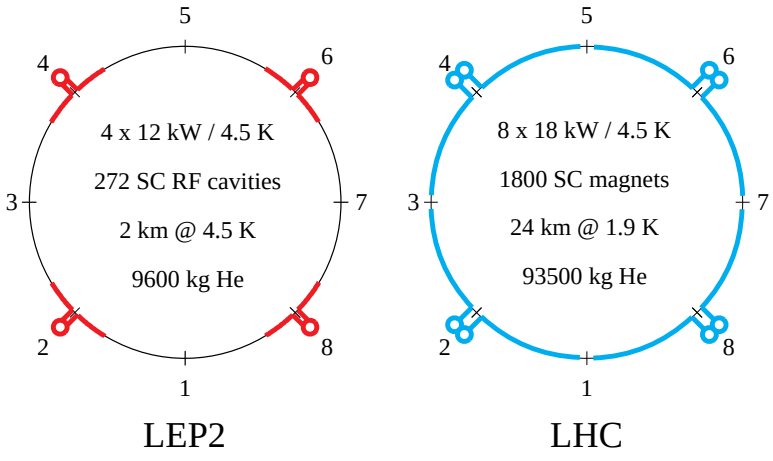

Figure 1 Overview of cryogenics for LEP2 and LHC

ACCELERATING HIGH-ENERGY LEPTONS IN SUPERCONDUCTING CAVITIES: THE LEP2 PROGRAMME

CERN has been operating since 1989 the LEP facility, a high-energy positron collider installed in a 26.7 km circumference underground of Geneva, Switzerland. This machine was primarily built to perfor of the vector bosons which mediate the electroweak interaction. In of energy by synchrotron radiation from the circulating leptons, LI of curvature and uses low-field, resistive electromagnets for beam the beam energy of LEP from 45 to 96 GeV and thus open the way fo W^+W^- pairs (the LEP2 programme), up to 272 superconducting acceler operating at 352 MHz with a total active length of about 400 m, ar four equidistant locations in long straight sections around the tu up to 150 m below ground level [4]. The four-cell cavities are ass four inside common cryomodules, cooled in a bath of saturated (boil bar [5]. Operation of the cavities at their nominal accelerating requires large-power refrigeration at 4.5 K (Table 1).

Table 1 Refrigeration loads of a LEP2 four-cavity cryomodule

Isothermal @ 4.5 K, Static	80	W
Isothermal @ 4.5 K, Dynamic	250	W
Liquefaction 4.5-290 K	0.8	g/s

Refrigeration is provided by four cryogenic plants producing eac equivalent, and ultimately capable, after upgrading, of 18 kW@4.5 plants, designed and constructed by two European suppliers, are compact design. The upper coldboxes, located at the surface, opera 20 K, and are connected by vertical interconnecting lines to 20-1 boxes installed in caverns at tunnel level [6]. As a consequence of in the procurement contracts and sound technical competition betw thermodynamic cycles feature high efficiency, with a measured performance of 225 W/W@4.5 K. A set of gas-shielded transfer lines, on either side of the lower coldboxes, distributes liquid helium to vapour from the cryomodules in the tunnel. Fully automatic operat system is achieved by means of an industrial, multiprocessor-base system running object-oriented software [7]. The 2400 kg helium in the four LEP2 sites can be stored in gaseous form at 2 MPa and amb The general layout of cryogenic equipment at a LEP2 site is sketched

Table 2 Refrigeration capacity of LEP2 cryoplants

Isothermal @ 4.5 K	10	kW
Non-isothermal @ 50-75 K	6.7	kW
Liquefaction 4.5-290 K	0.8	g/s

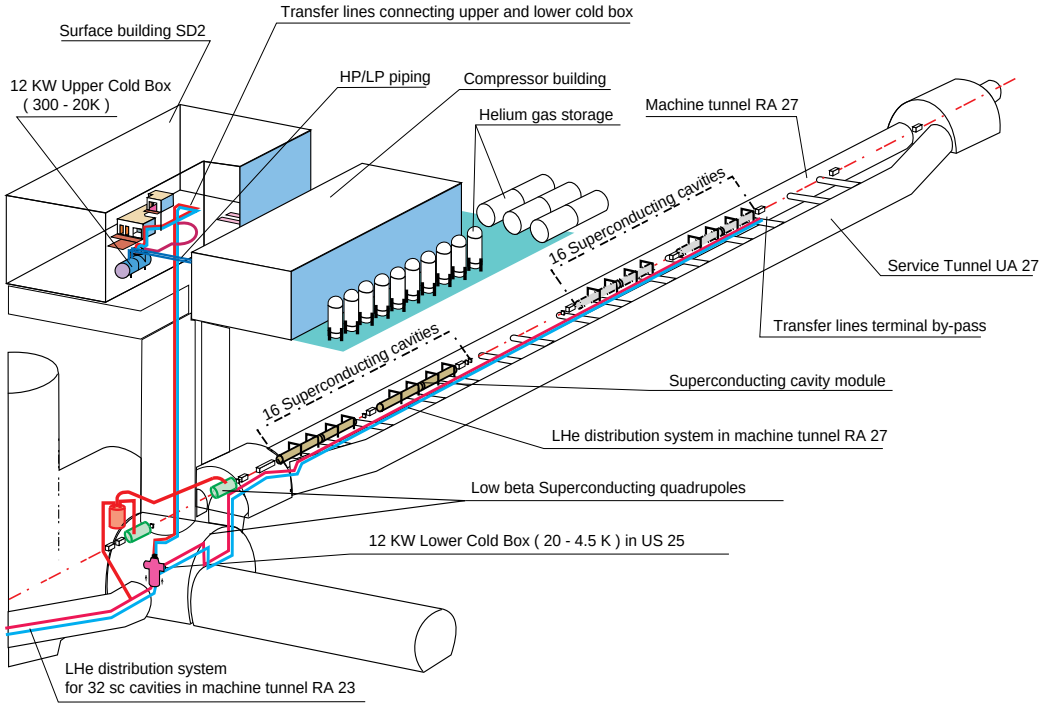

Figure 2 Overall view of cryogenics on a LEP2 site

All plants have been procured, installed and commissioned between 1
LEP is now currently operating with increasing numbers of supercor
gradually installed during programmed machine shutdowns [9]. The LEI
expected to be completed by 1998, and will produce physics until th

COLLIDING HADRONS GUIDED BY HIGH-FIELD SUPERCONDUCTING MAGNETS OPERATING IN SUPERFLUID HELIUM: THE LHC PROJECT

At the end of 1994, the CERN Council approved the construction of
Collider (LHC) project, a proton and ion collider with center-of-
TeV-per-constituent range. This machine, to be installed in the LEP
LEP2 operation, will allow to probe the fine structure of matter a
of 10^{-19} m, by recreating in the laboratory conditions of "temperat
in the very early universe. To guide and focus its stiff hadron bea
use of high-field superconducting magnets with a bending field of
pressurized superfluid helium at 1.9 K, over most of the circumfe
LHC cryogenic system, unprecedented in size and complexity [12], wi
four LEP2 refrigeration plants, adequately modified and upgraded,
new plants of similar capacity. At their lower-temperature end
coldboxes will generate a total of about 20 kW@1.8 K, using mult
pressure cryogenic compressors. The cryogenic power requirements o
cryoplants [13] are given in Table 3. Depending upon the particula
and equipment to be cooled in each of the eight sectors, four cryo
high-load sectors, and the other four, low-load sectors. Although c

capacity with the upgraded LEP2 refrigerators, the LHC cryogeni provide non-isothermal cooling, which will require substantial mod and equipment.

Table 3 Refrigeration capacity demands of LHC sector cryoplants

	50-75 K [kW]	4.5-20 K [kW]	4.7 K [kW]	1.8 K [kW]	20-290 K (*) [g/s]
High-load	31	4.3	0.80	2.80	35
Low-load	30	4.3	0.65	2.45	23

(*) For cooling the resistive upper section of HTS current leads

A cryogenic distribution system exploiting the specific properties will maintain the furthest magnets within 0.1 K of the temperatu plants, over the 3.3 km length of each sector (Figure 3). Effic multiple shielding and heat interception, will limit heat loads an refrigeration budgets within technically acceptable limits (Table 4)

Table 4 Distributed heat loads in LHC arcs [W/m]

	50-75 K	4.5-20 K	1.9 K
Heat inleak	6.38	0.13	0.27
Resistive heating	0.04	-	0.11
Beam-induced (ultimate)	-	1.35	0.05
Total	6.42	1.48	0.43

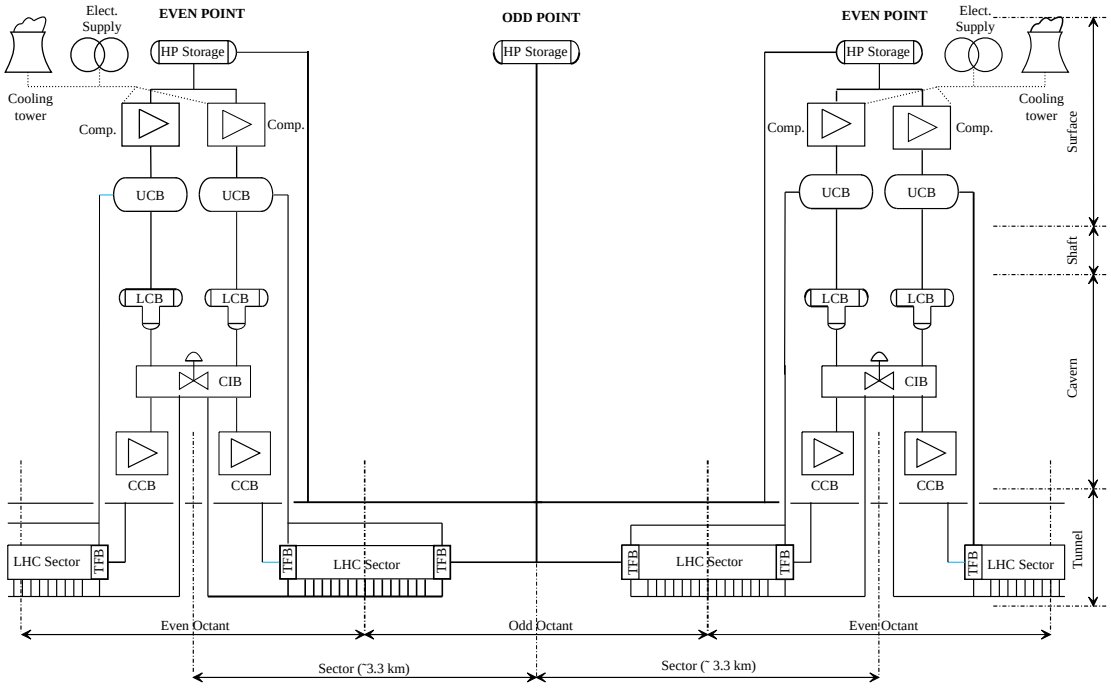

Figure 3 General architecture of LHC cryogenics

A vigorous development programme, conducted in collaboration w
laboratories and industry, has permitted to validate design choice
on prototype components, particularly as concerns cryostat desig
[14], thermohydraulics of two-phase superfluid helium [15], cryo
compressors [16, 17] and complete system tests on a magnet string
now in the beginning of its construction phase, and is expected
physics at full energy in 2005.

CONCLUSION : MEGASCIENCE AS MOTOR OF TECHNICAL DEVELOPMENT

Large projects in particle physics have stimulated the development
on an industrial scale, and created a reservoir of know-how and ex
Besides providing immediate returns to the work in progress, both
as long-term investments opening the way for the increased
superconductivity in science, technology and society.

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